Grass-lined Channel

Practice Description

A grass waterway constructed for the purpose of handling concentrated surface runoff in such a way as to prevent damage from erosion and siltation. This practice applies to sites where:

- concentrated runoff will cause erosion damage,
- a vegetative lining provides sufficient stability for the channel as designed,
- channel grades are generally less than 5% and
- space is available for a relatively large cross section.

Typical uses include roadside ditches, channels at property boundaries, outlets for diversions and stabilizing concentrated flow areas.

N. Klopfenstein, NRCS. Cole Co.

Establish permanent vegetation as quickly as possible so that grassed waterways can be used. Erosion control matting will provide immediate protection if the waterway is needed before grass is established.

Recommended Minimum Requirements

Prior to start of construction, grass-lined channels should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process. The channel should be built according to planned alignment, grade and cross section.

- **Cross Section:** Trapezoidal or parabolic
- **Side Slopes:** 3:1 or flatter for trapezoidal channels
- **Channel Stabilization:** Use mulch, erosion control blankets, turf reinforcement mats or other appropriate practices as specified in the design plan.
- **Outlet:** Channels should empty into sediment traps, detention/ retention basins or stable outlets.
- **Subsurface Drain:** Use in areas with seasonally high water tables or seepage problems.

Construction

Site Preparation

Determine exact location of underground utilities.

Install sediment traps or drains if needed.

Remove brush, trees and other debris from the construction area and dispose of properly.

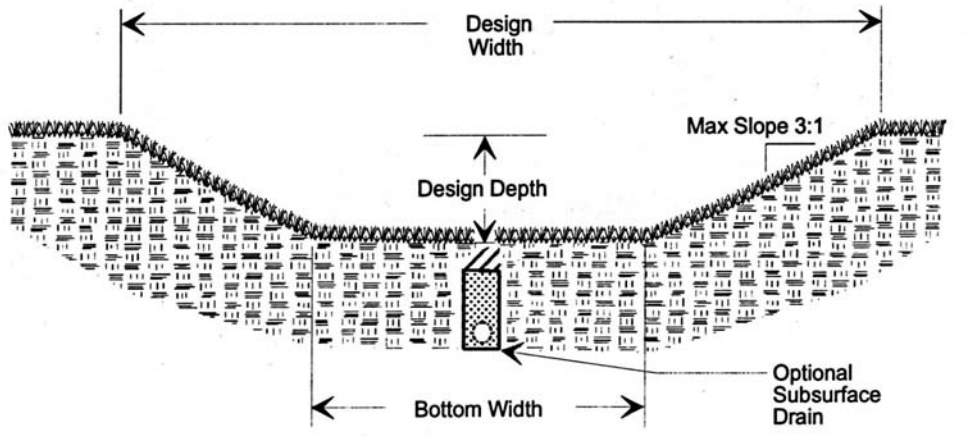


Figure 5.19 Typical Trapezoidal Grass-lined Channel

Grading

Excavate and shape the channel to dimensions shown on the design specification, removing and properly disposing of excess soil so surface water can enter the channel freely.

If subsurface drain is needed, install it offset to one side of the channel.

Provide topsoil as needed to grow grass on areas disturbed by construction.

Erosion Control

Protect all concentrated inflow points along the channel with erosion-resistant linings, riprap, sod or other appropriate measures.

Fertilize and seed or sod the channel immediately after grading; and protect with erosion control blankets, turf reinforcement mats or mulch according to the design plan.

Channel should outlet at a stable location.

Construction Verification

Check finished grade and cross section of channel throughout the length of the watercourse. Verify channel cross sections at several locations to avoid constrictions to flow.

Troubleshooting

Consult with registered design professional if any of the following occur:

- Variations in topography on site indicate channel will not function as intended. Changes in plan may be needed.
- Side slope cave ins resulting from unstable, high-water-table soil, steep banks or high-flow velocity. Most likely to occur on the outside of channel curves.
- Design specifications for seed variety, seeding dates or erosion control materials cannot be met; substitution may be required. Unapproved substitutions could result in channel erosion.

Maintenance

Inspect the channel following storm events both during and after grass cover is established; make needed repairs immediately.

Check the channel outlet and road crossings for blockage, sediment, bank instability, breaks and eroded areas remove any blockage and make repairs immediately.

Remove significant sediment and debris from the channel to maintain design cross section and grade and to prevent spot erosion.

Common Problems

Erosion occurs in channel before vegetation is fully established—repair, reseed and install erosion control blankets or turf reinforcement mats.

Gullying, head cutting or settling in channel; grade is too steep for a grass lining or drain was installed in the center of the channel, not off to the side—redesign the channel and utilize erosion-resistant lining.

Overbank erosion, spot erosion, channel meander or flooding—remove accumulated debris and sediment, and stabilize and revegetate trouble spots.

Ponding along channel; the approach is not properly graded or surface inlets are blocked—improve channel grade or remove blockage.

Erosion at channel outlet—install an outlet stabilization structure.

Sediment deposited at channel outlet; indicates channel or watershed erosion—find and repair the source of any channel erosion, stabilize the watershed, or install temporary diversion and sediment traps to protect the channel from sediment-laden runoff.

Riprap-lined Channel

Practice Description

Waterways with an erosion-resistant rock lining designed to carry concentrated runoff to a stable outlet. This practice applies where conditions are expected to be unsuitable for use of grass-lined channels, such as: 1) channels with average grades over 5%, continuous or prolonged flows occur, potential for damage from traffic exists, or soils are erodible and soil properties are not suitable for vegetation; 2) design velocities exceed 5 feet per second; 3) channel location warrants the use of increased protection; or 4) channel will have prolonged periods of wetness which will hinder growth of grass.

Becky Holland, Volunteer. Jackson Co.

Rock-lined channels, like this one in Independence, can be used in areas with high flow velocities or where vegetation is hard to establish.

Recommended Minimum Requirements

Prior to start of construction, riprap-lined channels should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process. The channel should be built according to planned alignment, grade and cross section.

- **Cross Section:** As shown in the design specifications
- **Side Slopes:** 2:1 or flatter
- **Riprap/Rock:** Size and gradation as shown in design specifications. Riprap should consist of a well-graded mixture of stone. Larger stone should predominate, with sufficient smaller sizes to

fill the voids between the stones. The diameter of the largest stone size should be not greater than 1.5 times the d_{50} size.

- **Riprap Thickness:** Minimum thickness of riprap should be 1.5 times the maximum stone diameter.
- **Stone or Rock Quality:** Select stone for riprap from field stone or quarry stone. The stone should be hard, angular, and highly chemical- and weather- resistant. The specific gravity of the individual stones should be at least 2.5.
- **Foundation:** Geotextile filter fabric or rock aggregate filter layer under the riprap
- **Outlet:** Stable, non-erosive

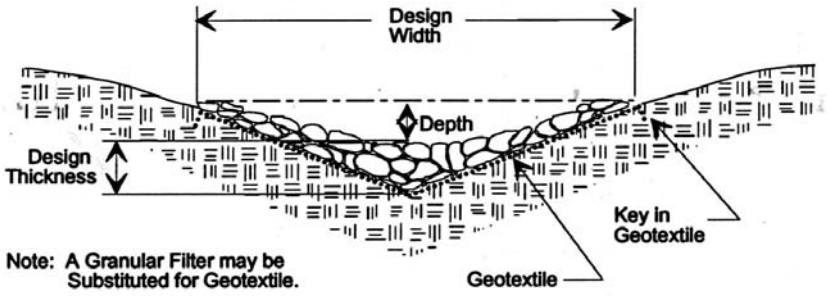


Figure 5.20 Typical V-shaped Riprap-lined Channel

Construction

Site Preparation

Determine exact location of underground utilities.

Remove brush, trees and other debris from the channel and spoil areas, and dispose of properly.

Excavate cross section to the lines and grades shown in design specifications. Overexcavate to allow for thickness of riprap and filter material.

Installation

Install geotextile fabric or aggregate in the excavated channel as a foundation for the riprap. Anchor fabric in accordance with design specifications.

As soon as the foundation is prepared, place the riprap to the thickness, depth and elevation shown in the design specifications. It should be a dense, uniform and well-graded mass with few voids.

Blend the finished rock surface with the surrounding land surface so there are no overfalls, channel constrictions or obstructions to flow.

Erosion Control

Stabilize channel inlet points and install needed outlet protection prior to or during channel construction.

Stabilize disturbed areas after construction is completed.

Construction Verification

Check finished grade and cross section of channel throughout the length of the watercourse. Verify channel cross sections at several locations to avoid flow constrictions.

Troubleshooting

Consult with registered design professional if any of the following occur:

- Variations in topography on site indicate channel will not function as intended; changes in plan may be needed.
- Design specifications for riprap sizing, filter fabric or aggregate filter cannot be met; substitution may be required. Unapproved substitutions could result in channel erosion.

Maintenance

Inspect channels at regular intervals and after storm events.

When stones have been displaced, remove any debris and replace the stones in such a way as to not restrict the flow of water.

Give special attention to outlets and points where concentrated flow enters the channel, and repair eroded areas promptly.

Check for sediment accumulation, piping, bank instability and scour holes; repair promptly.

Common Problems

Foundation excavation not deep enough or wide enough; may cause riprap to restrict channel flow and result in overflow and erosion—deepen channel and replace riprap.

Side slopes too steep; causes instability, rock material movement and bank failure—flatten side slopes.

Filter omitted or damaged during stone placement; may result in piping and bank instability—install filter and replace stone.

Riprap poorly graded or stones not placed to form a dense, stable channel lining; may result in rock displacement and erosion of the foundation—replace riprap with properly sized, well graded material.

Riprap installed smaller than specified; may result in rock displacement—selectively grouting over rock materials may stabilize the situation.

Riprap not extended far enough downstream; may result in undercutting—the channel should outlet on a stable location; extend riprap as needed.

Riprap not blended to ground surface; may result in gullying along edge of riprap—regrade riprap to blend with ground surface.

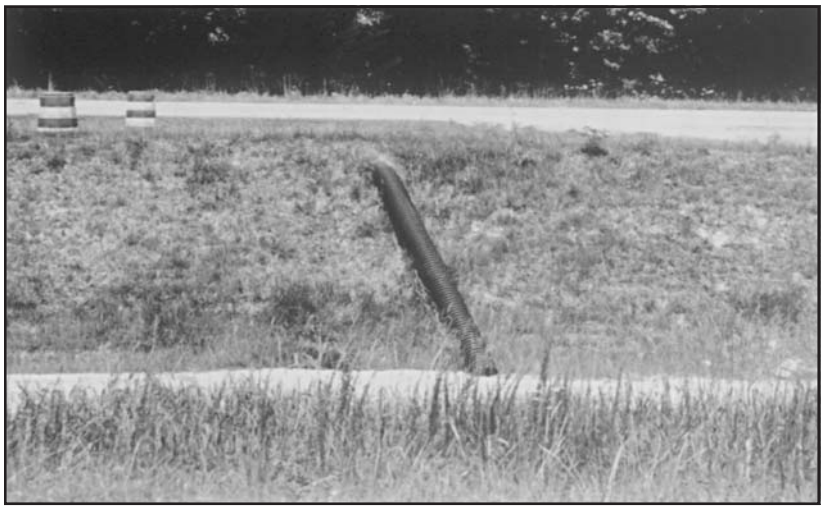
Riprap not installed until after washout of other materials has occurred—replace eroded material and install riprap.

Riprap just dumped and not properly shaped; may result in rock displacement and erosion—repair eroded area and reshape riprap to attain proper channel shape.

Temporary Slope Drains

Practice Description

A pipe or other conduit designed to convey concentrated runoff down the face of a cut or fill slope without causing erosion. This practice applies wherever stormwater runoff must be conveyed down a steep slope.



Courtesy of North Carolina DEHNR

Temporary slope drains can be used almost immediately to carry surface runoff down a steep slope, allowing vegetation a chance to become established.

Recommended Minimum Requirements

Prior to start of construction, temporary slope drains should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process.

- **Material:** Strong, flexible pipe, such as heavy-duty, non-perforated, corrugated plastic
- **Design Life:** 18 months or less
- **Inlet Section (optional):** Standard "T" or "L" flared-end section with metal toe plate
- **Inlet to pipe at top of slope:** Compacted fill over pipe with minimum dimensions of 1.5-foot depth, 4-foot top width and 6 inches higher than ridge

- **Outlet:** Pipe should extend beyond toe of slope and discharge into a sediment trap or basin unless the contributing drainage area is stable or undisturbed.

- **Pipe Size:** See Table 5.15 for sizes.

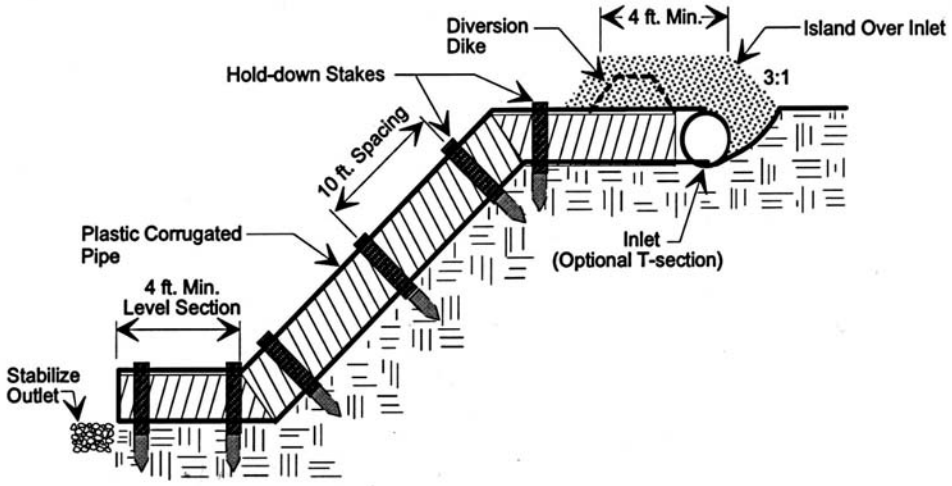


Figure 5.21 Typical Cross Section of Temporary Slope Drain with Optional T-section Inlet

Table 5.15 Pipe Size for Slope Drain

Maximum Drainage Area per Pipe	Minimum Pipe Diameter (inches)
0.5 acre	8 inches
0.75 acre	10 inches
1.0 acre	12 inches
> 1.0 acre	Individually Designed

Source: Indiana Handbook for Erosion Control in Developing Areas, 1992

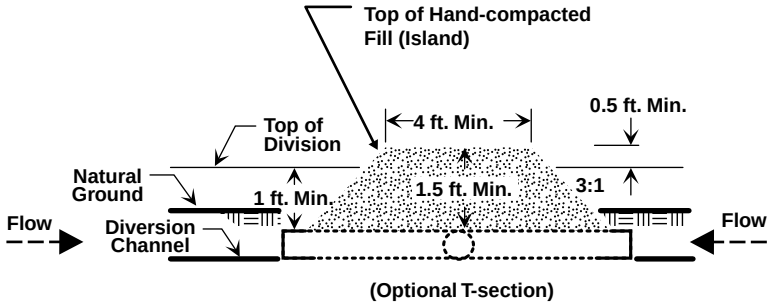


Figure 5.22 Detail of Inlet to a Temporary Slope Drain

Construction

Determine exact location of underground utilities.

Place temporary slope drains on undisturbed soil or well-compacted fill at locations and elevations shown on the plans.

Grade the diversion channel at the top of the slope toward the temporary slope drain. A stable, positive grade not exceeding 2% is needed. Slightly slope the section of pipe under the ridge.

Hand tamp the soil under and around the pipe in lifts not to exceed 6 inches.

Ensure that fill over the drain at the top of the slope has minimum dimensions of 1.5-foot depth (above top of pipe), 4-foot top width and 3:1 side slopes.

Ensure that all slope drain connections are secure and watertight.

Ensure that all fill material is well-compacted. Securely anchor the exposed section of the drain with grommets or stakes spaced no more than 10 feet apart.

Extend the drain beyond the toe of the slope and adequately protect outlet from erosion.

Make the settled, compacted diversion ridge no less than 1 foot above the top of the pipe at every point.

Erosion Control

Immediately stabilize all disturbed areas following construction with vegetation or other appropriate means of protection.

Construction Verification

Verify the dimensions shown on the plans for the following: diameter of pipe, inlet and outlet elevations, and diversion specifications (see *Temporary Diversions*).

Joints should be carefully inspected for separations or looseness.

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on site indicate temporary slope drains will not function as intended.

Maintenance

Inspect slope drains and supporting diversions once a week and after every storm event.

Check the inlet for sediment or trash accumulation; clear and restore to proper condition.

Check the fill over the pipe for settlement, cracking or piping holes; repair immediately.

Check for holes where the pipe emerges from the ridge; repair immediately.

Check the conduit for evidence of leaks or inadequate anchoring; repair immediately.

Check the outlet for erosion or sedimentation; clean and repair, or extend if necessary.

Once slopes have been stabilized, remove the temporary diversions and slope drains, and stabilize all disturbed areas.

Common Problems

Overtopping caused by undersized or blocked pipe; drainage area may be too large—install additional pipes and remove debris frequently.

Overtopping caused by improper grade of channel and ridge—regrade to provide positive drainage.

Overtopping due to poor entrance conditions and trash buildup at pipe inlet—deepen and widen the channel at the pipe entrance; inspect and clear inlet frequently.

Erosion at outlet—extend pipe to a stable grade or an outlet stabilization structure as needed.

Pipe separates or is displaced—tie the pipe down and secure the joints.

Animals going into the pipe outlet—install free swinging animal guard.

Subsurface Drains

Practice Description

A perforated pipe or continuous layer of porous material installed below the ground surface that intercepts, collects and carries excessive groundwater to a stable outlet. Subsurface drains by themselves do not provide erosion control.

The purpose of a subsurface drain is to improve soil moisture conditions, vegetation growth and ground stability. Subsurface drains also prevent wet, soft ground from interfering with construction activities. Drains may be constructed using a gravel-filled trench, perforated pipe in gravel bedding or manufactured drain panel products. This practice applies where groundwater is at or near the ground surface or where adequate drainage cannot be provided for surface runoff.

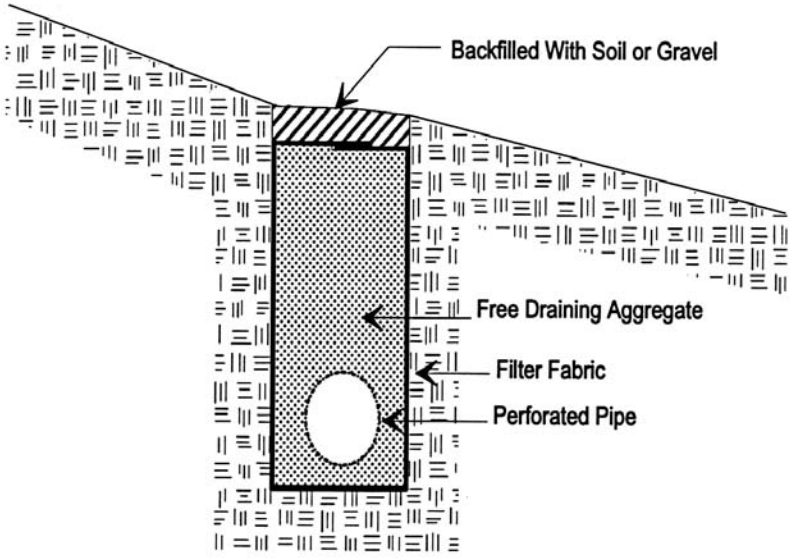
Bob Clay, MDNR. Nodaway County.

A gravel-filled trench is one of several ways to solve subsurface drainage problems. Note safety barrier around the trench.

Recommended Minimum Requirements

Prior to start of construction, subsurface drains should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process.

Drainage system layout, depth, construction details and specifications should be included in the design. Some aspects of the design may depend on site specific conditions not known or only estimated prior to installation.



Detail of Typical Subsurface Drain Construntion

Figure 5.23 Typical Installation of Subsurface Drain

- **Layout and Depth:** Generally, a depth of 3 feet and a spacing of 50 feet will be adequate.
  - Depth: Depth of the drain will determine how much the water table is lowered.
    - Maximum: Limited by the impermeable layer, and if pipe is used, by the allowable load on the pipe
    - Minimum: 2 feet under normal conditions
  - Spacing: Dependent on soil permeability and the depth of the drain
  - Multiple Drains: Determining the required spacing can be difficult. Install the first drain. Install an additional drain if seepage or high water table problems occur.

- **Location:** Over 50 feet from any trees

- **Grade:** Grade trench according to the design plan to prevent siltation into the drain. Steep grades should be avoided.

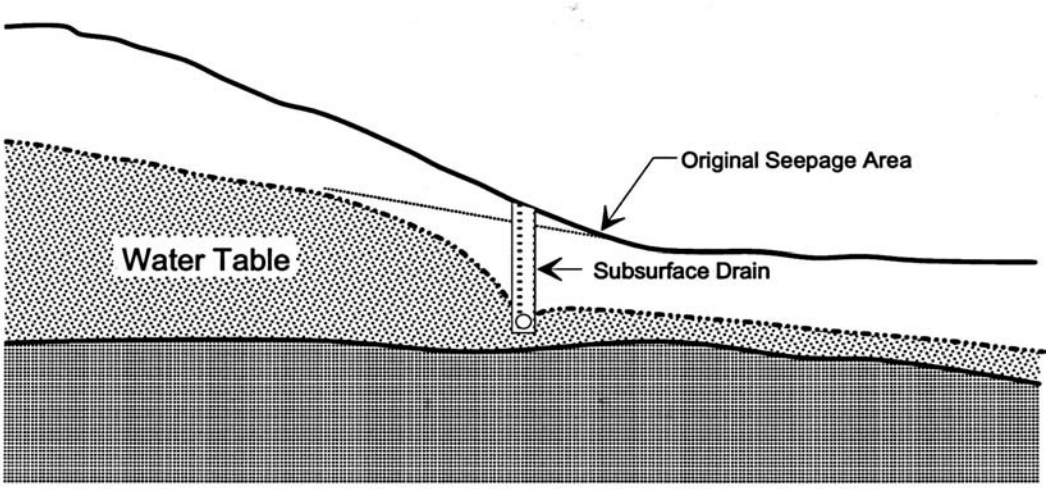


Figure 5.24 Detail of Typical Subsurface Drain Construction

- **Gravel Bedding:** Typically 3 inches or more of gravel placed completely around the drain and graded to prevent the infiltration of fine-grained soils into the drain

- **Filter:** As specified in design plan; determined by soil permeability. Usually filter fabric, although gravel bedding can be designed as a filter to prevent migration of fines.

- **Outlet:** To a stable watercourse, with outlet above the mean water level in the receiving channel. Protect drains from erosion, undermining, damage from periods of submergence and the entry of small animals.

- **Clean-outs:** May be required for long sections of drain

- **Materials:** Perforated, continuous closed-joint pipes of corrugated plastic, concrete, corrugated metal or bituminous fiber
  Strength and Durability: Should meet the requirements of the site in accordance with the manufacturer's specifications

Construction

Installation

Determine exact location of any underground utilities.

Dig a trench to specified grade at least 3 inches (or as shown on the design) below the design bottom elevation of the pipe to accommodate the gravel bedding or filter material.

Line trench with filter cloth, providing enough material to overlap over the top of the finished gravel bedding. This helps prevent movement of soil into the gravel.

Lay pipe on the design grade and elevation avoiding reverse grade or low spots. Do not use damaged, deformed, warped or otherwise unsuitable pipe.

Place bedding material around pipe with at least 3 inches (or as shown on the design) of material on all sides. Place gravel around drains for proper bedding and improved flow of groundwater into the drain.

Ensure that gravel for bedding around flexible pipe does not exceed $^{3}/_{4}$ inch in size to prevent damage to the pipe.

Fold filter cloth over the top of the gravel bedding.

Backfill immediately after placement of the pipe and bedding. Ensure that the material does not contain rocks or other sharp objects and place it in the trench in a manner that will not damage or displace the pipe. Overfill the trench slightly to allow for settlement.

Install clean-outs for maintenance as shown on design plan.

Construct the outlet above the mean water level in the receiving channel. For the outlet section of the drain, use at least 10 feet of non-perforated corrugated metal, cast iron, steel or heavy-duty plastic pipe. Cover at least $^{2}/_{3}$ of the pipe length with well compacted soil.

Place a suitable animal guard securely over the pipe outlet to keep out rodents.

Cap the upper end of each drain with a standard cap made for this purpose or with concrete or other suitable material to prevent soil from entering the open end.

Erosion Control

Stabilize any soft, yielding soils under the drain with gravel or other suitable material.

Keep the settled fill over the pipe outlet slightly higher than the surrounding ground to prevent erosion and wash out from surface runoff.

Safety

Narrow trenches are subject to collapse and can be a safety hazard to persons in the trench. No person should enter a trench without shoring protection or properly sloping the sides of the trench.

Construction Verification

Verify the dimensions shown on the plans for the following: location and length, depth and cross section of trench.

The dimensions and specifications of the aggregate used in the bedding and manufactured materials such as pipe, tile or panel drain should be verified.

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on site indicate subsurface drains will not function as intended.
- Design specifications for aggregate or manufactured products cannot be met; substitutions may be required. Unapproved substitutions could result in failure of the drain to function as intended.

Maintenance

Check subsurface drains periodically to ensure that they are free-flowing and not clogged with sediment.

Keep outlet clean and free of debris.

Keep surface inlets open and free of sediment and other debris.

Trees located too close to a subsurface drain often clog the system with their roots. If a drain becomes clogged, relocate the drain or remove the trees.

Where drains are crossed by heavy vehicles, check the pipe to ensure that it is not crushed.

Common Problems

Bedding material is not free-draining or does not provide filtration for pipe—replace with properly graded material or filter fabric.

Pipe is crushed by construction traffic, resulting in poor drain performance—replace damaged section of pipe.

Rock Outlets

Practice Description

A structure constructed to control erosion at the outlet of a channel or conduit. A rock outlet is an apron constructed of rock riprap designed to prevent scour at stormwater outlets, and to minimize the potential for downstream erosion by reducing the velocity and energy of concentrated stormwater flows.

This practice applies where the discharge velocity of a pipe, box culvert, diversion or other water conveyance structure exceeds the permissible velocity of the receiving area.

Becky Holland, NRCS Volunteer. Jackson Co.

Riprap at the downstream end of a rock outlet should be level with or slightly below the receiving channel to prevent overfalls and the resulting scouring and erosion.

Recommended Minimum Requirements

Prior to start of construction, rock outlets should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process. The rock outlet should be built according to planned alignment, grade, cross section and length.

- **Grading:** There should be a smooth transition between the rock outlet and the receiving channel; that is, the elevation of the rock apron at the downstream end should be at the same elevation as the bottom of the receiving channel.

- **Alignment:** If possible, the alignment of the rock outlet should be straight throughout its length. If a curve is required, it should be located in the upstream section of the outlet.

- **Riprap:** Riprap should consist of a well-graded mixture of rock (a range of sizes). Larger rock should predominate, with sufficient smaller sizes to fill the voids between the rock. The diameter of the largest rock size should be not greater than 1.5 times the d_{50} size.

- **Riprap Thickness and Length:** Minimum thickness of riprap should be 1.5 times the maximum rock diameter. Length of riprap must be designed such that erosion at the outlet is minimal for receiving material.

- **Rock Quality:** Select rock for riprap from field stone or quarry stone. The rock should be hard, angular, and highly chemical and weather resistant. The specific gravity of the individual stones should be at least 2.5.

- **Filter:** Install or construct between the rock riprap and the subgrade to prevent undermining of the structure due to piping of fine-grained subgrade soil. The filter can consist of either a properly graded mineral (sand/gravel) layer or a manufactured geotextile fabric or combination of both.

- **Toewalls:** According to the design plan; may be needed around full perimeter to prevent maintenance problems.

Construction

Clear the foundation area of trees, stumps, brush, sod and all other unsuitable material which would interfere with construction of the rock outlet.

Excavate the apron area subgrade below design elevation to allow for thickness of the filter layer and the riprap.

Compact any fill used in the subgrade to the specified maximum density as determined by testing, and smooth enough to protect fabric (if used) from tearing.

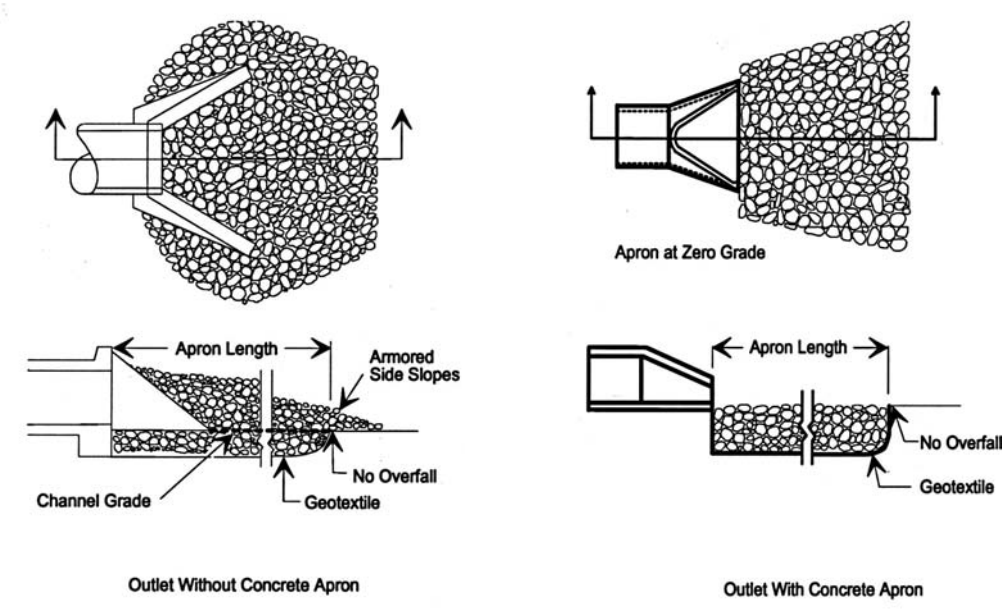


Figure 5.25 Typical Rock Outlet

Construction of Geotextile Filter

Place the geotextile fabric on the compacted smooth foundation. If more than one fabric piece is needed, the upstream piece should overlap the downstream piece by at least 1.5 feet in all directions.

If the geotextile fabric tears when placing the riprap, repair immediately by laying and stapling a piece of fabric over the damaged area, overlapping the undamaged areas by at least 1.5 feet in all directions.

Construction of Sand/Gravel Filter

Material used should be a clean, free draining granular material with sufficient fine material to prevent subgrade from passing through the filter layer. Gradation should be specified in the design and verified by testing.

Place gravel in a layer of uniform thickness and compact as specified in the design. Care should be taken to avoid segregation of particle sizes during placement.

Riprap

Install the riprap to the lines and elevations shown in the design. If there is no defined channel, the final cross-section should be level or slightly depressed in the middle; if well defined, the filter and riprap should extend to the top of the bank.

Make sure the top of the rock apron is level with or slightly below the receiving stream. (Riprap should not restrict the channel or produce an overfall.)

Blend the riprap smoothly to the surrounding grade.

Erosion Control

Stabilize all disturbed areas immediately following installation.

Construction Verification

Check finished grade and configuration of structure.

Check conformance of materials to specifications.

Troubleshooting

Consult with registered design professional if any of the following occur:

- Variations in topography on site indicate rock outlet will not function as intended; changes in plan may be needed.
- Design specifications for riprap, sand/gravel filter material or geotextile cannot be met; substitution may be required. Unapproved substitutions could result in failure of the outlet.

Maintenance

Inspect rock outlets after storm events for stone displacement and for erosion at the sides and ends of the apron.

Make needed repairs immediately; use appropriate size stone, and do not place them above finished grade.

Common Problems

Foundation not excavated deep enough or wide enough; riprap restricts the flow cross section, resulting in erosion around the apron and scour holes at the outlet—remove filter and riprap, widen/deepen channel, replace filter and riprap.

Rock apron not on zero grade; may result in downstream erosion—modify grade or install grade stabilization measures at downstream edge of apron.

Riprap installed smaller than specified; results in rock displacement—selective grouting over the rock materials may stabilize the situation, or replace riprap with larger size.

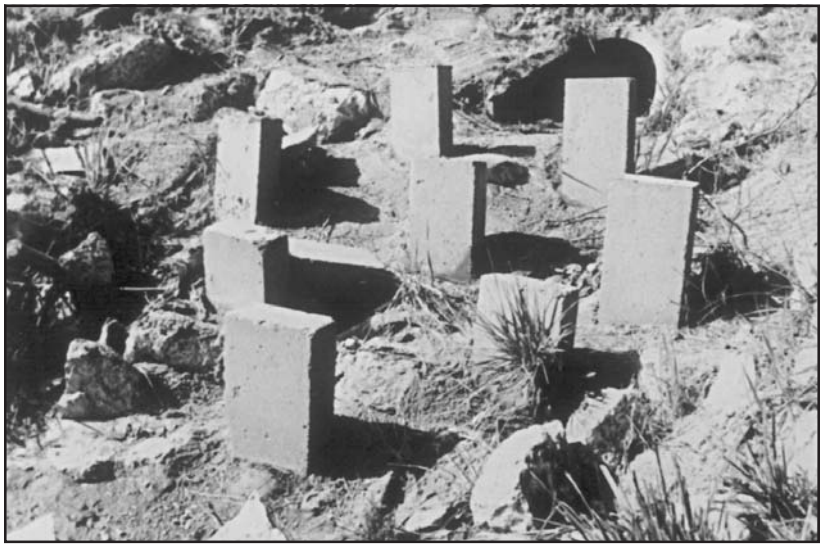
Riprap not extended enough to reach a stable section of channel; results in downstream erosion—extend length of outlet.

No filter installed under the riprap; results in stone displacement and erosion of the foundation—remove riprap and install filter.

Energy Dissipators

Practice Description

This practice is designed to prevent erosion at the outlet of a channel or conduit by reducing the velocity of flow and dissipating the energy. Energy dissipators usually consist of a riprap-lined apron, a reinforced concrete flume with concrete baffles or a reinforced concrete box with chambers or baffles. This practice applies wherever high velocity discharge must be released on erodible material.



C. Rahm, NRCS. St. Charles Co.

Energy dissipators reduce flow velocities so that water can exit at nonerosive rates.

Recommended Minimum Requirements

Prior to start of construction, energy dissipators should be designed by a registered design professional. Plans and specifications should be referred to by field personnel throughout the construction process.

- **Capacity:** 10-year peak runoff or the design discharge of the water conveyance structure, whichever is greater
- **Size:** The energy dissipator should be individually designed. It must be long enough to dissipate runoff energy. The width should be designed to match the configuration of the receiving channel.

Riprap Structures

- **Apron:** Should have zero grade with no overfall at the end of the apron.
- **Alignment:** Should be straight throughout its entire length, but if a curve is necessary to align the structure with the receiving stream, locate the curve in the upstream section of the structure.
- **Riprap:** Riprap should consist of a well-graded mixture of stone. Larger stone should predominate, with sufficient smaller sizes to fill the voids between the stones. The diameter of the largest stone size should be not greater than 1.5 times the d_{50} size.
- **Riprap Thickness:** Minimum thickness of riprap should be 1.5 times the maximum stone diameter.
- **Stone Quality:** Select stone for riprap from field stone or quarry stone. The stone should be hard, angular, and highly chemical and weather resistant. The specific gravity of the individual stones should be at least 2.5.
- **Filter:** Install a filter to prevent soil movement through the openings in the riprap. The filter should consist of a graded gravel layer or a synthetic filter cloth.

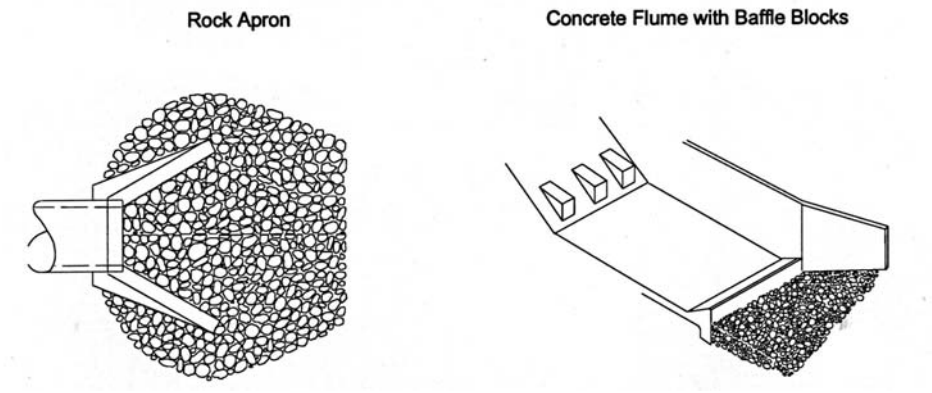


Figure 5.26 Common Energy Dissipators

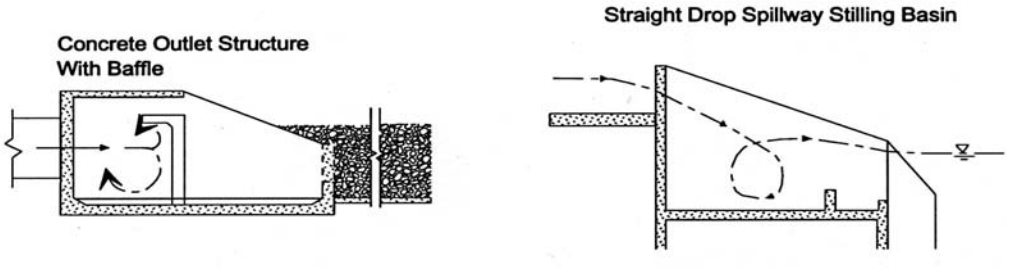


Figure 5. 27 More Common Energy Dissipators

Concrete Structures

- **Structure:** Requirements for concrete structures will vary according to the specific design configuration. The structure should conform to the dimensions, grades and alignments shown on the plans and specifications.

Construction

Site Preparation

Completely remove stumps, roots and other debris from the construction area. Fill depressions caused by clearing and grubbing operations with clean, non-organic soil.

Grade the site to the lines and grades shown on the plans. Compact any fill required in the subgrade to the density of the surrounding undisturbed material.

Riprap Structures

Ensure that the subgrade for the filter and riprap follows the required lines and grades shown in the plan. Low areas in the subgrade on undisturbed soil may also be filled by increasing the riprap thickness.

Filter cloth must meet design requirements and be properly protected from punching or tearing during installation. Repair any damage by removing the riprap and placing another piece of filter cloth over the damaged area. All connecting joints should overlap a minimum of 1.5 feet. If the damage is extensive, replace the entire filter cloth.

Riprap may be placed by equipment. Care should be taken to avoid damaging the filter.

Construct the apron on zero grade with no overfall at the end. Make the top of the riprap at the downstream end level with the receiving area or slightly below it.

Concrete Structures

Reinforcing steel should be placed in strict accordance with the design plans and maintained in the proper position during the pouring of concrete. Concrete should be placed in horizontal layers not exceeding 24-inches in thickness or as specified in the design, and consolidated by mechanical vibrating equipment supplemented by hand-spading, rodding or tamping.

Concrete should be placed in sturdy wood or metal forms, adequately supported to prevent deformation. Forms should be oiled prior to placement to prevent bonding between concrete and forms.

If possible, concrete should not be placed during inclement weather or periods of temperature extremes. If temperature extremes cannot be avoided, American Concrete Institute (ACI) guidelines for placement of concrete during such extremes should be consulted.

Concrete should be allowed to cure as called for in the plans and specifications. Typically, the surface should be kept wet during curing by covering it with wet burlap sacks or other means. Design strengths should be confirmed by laboratory tests on representative cylinders made during concrete placement. Form work should be left in place until the concrete attains design strength.

Erosion Control

Immediately after construction, stabilize all disturbed areas with vegetation.

Construction Verification

Check finished structures for conformance with design specifications.

Troubleshooting

Consult with a registered design professional if any of the following occur:

- Variations in topography on site indicate energy dissipator will not function as intended.
- Design specifications for riprap, filter fabric, concrete, reinforcing steel or backfill cannot be met; substitutions may be required. Unapproved substitutions could lead to failure.

Maintenance

Inspect riprap outlet structures after heavy rains to see if any erosion around or below the riprap has taken place or if stones have been dislodged. Check concrete structures for cracks and movement. Immediately make all needed repairs to prevent further damage.

Common Problems

Riprap Structures

Riprap restricts the flow cross section; resulting in erosion around the apron and scour holes at the outlet—remove filter and riprap, widen/deepen channel, replace filter and riprap.

Erosion at downstream end—modify grade or install grade stabilization measures at downstream edge of apron.

Rock displacement—replace riprap with larger size.

Stone displacement and erosion of the foundation—remove riprap and install filter; replace riprap.

Concrete Structures

Poor foundation preparation, resulting in movement of base, cracking or complete failure of the concrete structures— inspect foundation thoroughly before concrete placement.

Concrete poured during inclement weather conditions, resulting in excessive spalling, cracking or erosion of concrete surface—prohibit

placement during inclement weather or follow accepted guidelines for such conditions.

Concrete does not meet specification, resulting in low strength, cracking, spalling or other undesirable conditions—perform sufficient testing to verify concrete specifications.